Preface: Nonclassical Transport

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Transport phenomena in highly heterogeneous media can be dramatically different from those in homogeneous media and therefore are of great fundamental and practical interest. Anomalous transport occurs in semiconductor physics, plasma physics, astrophysics, biology, and other areas. It plays an especially important role in hydrogeology because it may govern the rate of migration and degree of dispersion of groundwater contaminants from hazardous waste sites.

The series of four articles in this special section of *Vadose Zone Journal* is devoted to transport phenomena in heterogeneous media in the context of geologic disposal of radioactive waste. It contains the results of joint investigations performed at the Nuclear Safety Institute of the Russian Academy of Sciences and Lawrence Berkeley National Laboratory in California. The work was supported by the U.S. DOE (under Contract No. DE-AC02-05CH11231).

The problems addressed in this research involve a broad range of space and time scales and were approached using modern methods of theoretical and computational physics, such as scaling analysis and diagrammatic techniques used before in critical phenomena theory. Special attention is paid to the asymptotics of concentration behavior (concentration tails). This issue is exceptionally important for the reliability assessments of radioactive waste disposal because, depending on the structure of the tails, concentrations at large distances from the source can differ by many orders of magnitude.

In the first paper of this special section, Bolshov et al. (2008b) present an overview of field and laboratory observations that demonstrate nonclassical flow and transport behavior in geologic media. It is recognized that natural fracture networks as a rule have fractal geometry and can be classified as percolation systems. This is one of the main factors giving rise to anomalous transport in geologic media. Another important factor is the presence of contaminant traps provided by low-permeable rock matrix and dead-ends of fracture percolation clusters. Physical concepts to describe transport phenomena in fractured rocks are discussed.

The second paper (Dykhne et al., 2008) is devoted to the analysis of diffusion in heterogeneous media with sharply contrasting properties. The authors show that as time progresses, three different transport regimes can be realized in the model. Here, an intermediate regime corresponds to subdiffusion. The change of regimes results in a complex structure of concentration tails, with the shapes of the more-distant tail segments determined by earlier-time transport behavior.

In the third paper (Bolshov et al., 2008a), new elements are developed to generalize the dual-porosity model for moisture infiltration and solute transport in unsaturated rocks, taking into account fractal aspects of the percolation process. It is shown that the solute transport regime is determined by a competition of two mechanisms: random advection through a fracture network and trapping caused by sharply contrasting properties of the medium. As a

result, superdiffusive, subdiffusive, or classical diffusive regimes may occur. The complex structure of concentration tails and effects due to medium characteristic fluctuations is also discussed.

In the fourth paper, Goloviznin et al. (2008) develop a stochastic random walk numerical model of anomalous diffusion to simulate solute transport in highly heterogeneous media. Solutions of the one- and symmetric two-dimensional stochastic problem are compared with computations performed on the basis of fractional advection—diffusion equation models. The new model is in reasonable agreement with experimental data on solute transport in highly heterogeneous media.

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